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THE NEED FOR UNEXPLODED ORDNANCE REMEDIATION TECHNOLOGY

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Prepared for
Office of the Under Secretary of Defense (Acquisition and Technology)
Deputy Director, Test and Evaluation (Test Facilities and Resources)

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PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) for the Office of the Under Secretary of Defense (Acquisition and Technology), Deputy Director, Test and Evaluation (Test Facilities and Resources), under a task entitled "Resource Analysis for Test and Evaluation." The objective of the task is to conduct cost analyses that lead to improved planning and programming of test resources. This document describes the potential requirement for DoD remediation of unexploded ordnance at test ranges. It provides a starting point for analysis of the costs and resources involved.

This work was reviewed within IDA by K. M. Olver.

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FIGURE

A. INTRODUCTION

Past military activities and munitions disposal practices have caused extensive contamination of the world's land and waterways with unexploded ordnance. Environmental, public safety, and defense mission requirements are driving a move to remediate these contaminated areas. The variety of unexploded ordnance (from land mines to submunitions) and the extent of contamination (around the world) pose a challenge that will require the development and application of advanced technology to overcome. Increasing public concern and more stringent federal, state, and local environmental regulations make finding technical solutions to the problem of effectively and efficiently locating, identifying, and remediating unexploded ordnance contamination even more urgent.

In this document, we focus on the unexploded ordnance problem as it relates to the Department of Defense (DoD) Major Range and Test Facility Base (MRTFB).[1] The MRTFB appears to have unexploded ordnance contamination and environmental conditions representative of those found at various sites around the world. We present an overview of the MRTFB to reveal the ranges with the most extensive unexploded ordnance contamination.

In addition, we provide general information on the natural environment at these ranges that hamper the development of detection and remediation technologies. We discuss the factors driving the need to detect and remediate areas of the test ranges and present the latest available information on expected regulatory actions. We also identify opportunities, within DoD programs, for supporting research and development in the area of unexploded ordnance detection and remediation. Finally, conclusions are drawn as to the scale of the technology requirement and the possible effect of cost considerations on the factors driving the requirement for remediation.

B. UNEXPLODED ORDNANCE ON TEST RANGES

Figure 1 shows the 22 MRTFB test and evaluation activities managed by the three military services. Together, they encompass approximately 50 percent of the DoD land in the continental United States, 243,000 square miles of water surface, and 221,000 square miles of airspace. These activities provide the full spectrum of test and evaluation support

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[1] The MRTFB consists of 22 Department of Defense facilities that together provide test and evaluation support for acquisition programs.

for the Department of Defense's major weapon system acquisition programs. Due to their unique capabilities and expertise, these facilities may also be used to support research, development, test and evaluation requirements of other government agencies and private industry. The MRTFB has also been used for military training activities over the years.

Today, military planners regularly evaluate the need to use fuzed high-explosive ordnance in testing and training. In cases where an explosive reaction is not necessary, inert ordnance is used. Past practices did not always incorporate such considerations. As a result, duds (live ordnance that failed to explode as planned), inert ordnance, and unfuzed high-explosive ordnance can all be found in the same area. This mix of ordnance complicates identification and remediation efforts. Unexploded ordnance is a potentially significant problem for installations that have been used for munitions and missile testing and troop training.

It is impossible to accurately predict the extent of unexploded ordnance contamination at the MRTFB. Quantitative data on range activities before the late 1970s, such as accurate firing records, do not exist in most cases. As a result, range officials are unable to state with certainty which areas of the range have been used for explosive ordnance testing and training activities. In addition, they are unable to predict with certainty the types of ordnance likely to be present or the possible numbers of unexploded ordnance in a particular area. Such uncertainty was demonstrated several years ago when a large amount of ordnance was unearthed during construction for the Underwater Explosions and Surface Testing test pond at Aberdeen Proving Ground. Records had not indicated that the types of munitions might be present.

MRTFB installations that have had major ordnance and missile activities include: Aberdeen Proving Ground, Dugway Proving Ground, White Sands Missile Range, Yuma Proving Ground, the Naval Air Warfare Center Weapons Division at China Lake, and the Air Force Development Test Center at Eglin Air Force Base. The remainder of this section describes of the relevant test mission, history, and types of ordnance tested at these installations.

1. Aberdeen Proving Ground

In 1917, the Army established Aberdeen Proving Ground (APG) along the Chesapeake Bay in Maryland. APG provides test support for items such as artillery

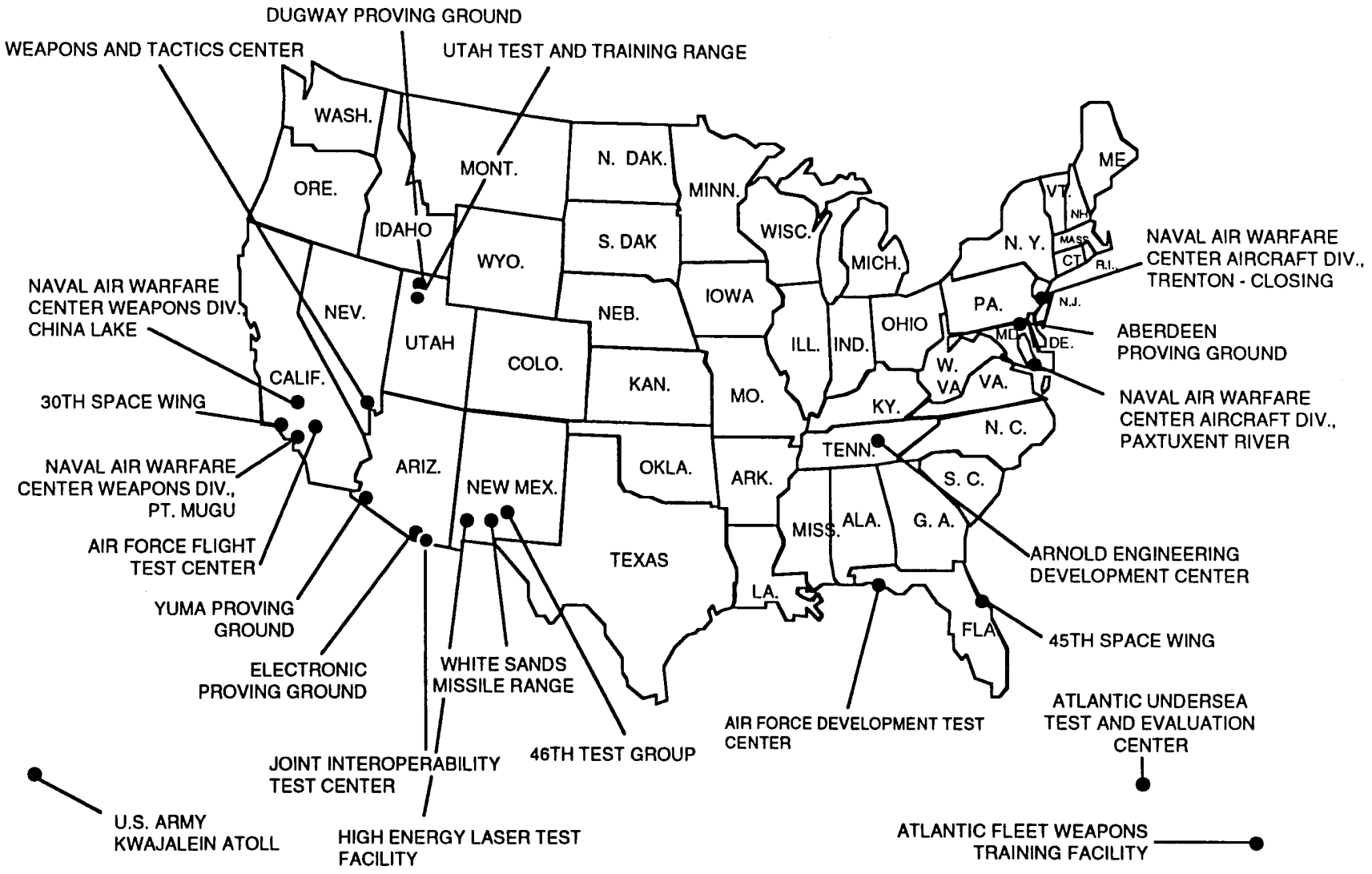

Figure 1. Locations of Major Range and Test Facility Base Activities

weapon systems, ammunition, mortars, mines, grenades, pyrotechnics, infantry weapons, small arms ammunition, recoilless rifles, armored vehicles, armor, and trucks. About 79,000 acres of land and water have been used for firing and explosive testing at the proving ground. The current firing ranges include: the Main Front Area with approximately 28 firing positions with capability for firing weapons of all calibers out to about 22,000 meters; the Mulberry Point and Plate Range with approximately 26 firing positions for testing 40-millimeter to 175-millimeter ammunition and the ability to fire over water out to approximately 20,000 meters; the Michaelsville Range with approximately 26 firing positions for testing small arms up to 40 millimeters; eighteen armor test ranges that permit shooting at armor plate and armored vehicles with all types of weapons; and fifteen static detonation areas that permit evaluation of warheads, mines, and demolitions, including blast and fragmentation [1 and 2].

2. Dugway Proving Ground

In 1942, the Army established Dugway Proving Ground (DPG) 80 miles southwest of Salt Lake City, Utah. The 1,315-square-mile test range provides test support in the following areas: chemical warfare defensive systems and protective items, the characterization of smokes and obscurants, conventional munitions, and air vehicle testing. DPG facilities include several test grids for chemical munitions testing; a mortar range facility for firing 4.2-inch, 81-millimeter, and 60-millimeter mortars; a howitzer range for firing large caliber weapons; an artillery range; and the West Granite Range developed for firing chemical projectiles [2 and 3].

3. White Sands Missile Range

In 1945, the Army established White Sands Missile Range (WSMR) on a 4,000–square mile tract in southern New Mexico about 50 miles north of El Paso, Texas. WSMR provides test support for missile, rocket, and other systems. The main range at WSMR is approximately 37 miles wide by 100 miles long. Two hazardous impact areas are located in the middle and upper areas of the range, which are used to receive various ground-launched and air-launched missiles. In recent years, WSMR has provided test support for the Multiple Launch Rocket System, the Patriot, the Navy's Standard Missile, the Air Force's Air Intercept Missile, the Lance, the Rolling Airframe Missile, and the Short Range Attack Missile II programs [2 and 4].

4. Yuma Proving Ground

Yuma Proving Ground (YPG) encompasses more than 1,300 square miles in the Soran Desert in the southwestern part of Arizona. The desert terrain found at YPG provides testers with desert conditions similar to those found anywhere in the world. The terrain at YPG is visibly scarred by the impact of ordnance from testing of artillery, mortars, mines, and ground and aircraft weapons. YPG has two primary ranges, Kofa and Cibola. The Kofa range is approximately 8,000 meters wide and provides ranges up to 75,000 meters. It includes various prepared impact areas available for evaluating the deployment, functioning, and recovery of submunitions and other munitions for post-firing analysis. The Cibola range, which is approximately 20 miles by 30 miles in size, is the primary test area used for aircraft armament, fire control, and manned and unmanned aircraft testing [2 and 5].

5. Naval Air Warfare Center Weapons Division

The Naval Air Warfare Center Weapons Division at China Lake is located in the upper Mojave Desert, 150 miles northeast of Los Angeles, California. The Weapons Division conducts test and evaluation of air- and surface-launched weapons, electronic warfare systems, missiles, life-support systems, and parachute systems. The nearly one-million-acre land test range includes air weapons, air tactics, and military target ranges. The air weapons range is primarily for the test and evaluation of fire-control and bombing systems, guided weapons, air-to-surface missiles, and unguided bombs against fixed and moving ground targets. The air tactics range allows development and evaluation of air-to-surface attack tactics and weapon-delivery techniques and training of fleet pilots. The military target range is used for training in weapons delivery against such targets as bridges, tunnels, tanks, convoys, surface-to-air sites and gun emplacements. The Weapons Division also contains guided missile ranges, explosive test ranges, and a live ordnance environmental test facility [2]. Several years ago, at the urging of state officials, officials at the China Lake facility undertook an effort to clear the facility of surface ordnance. This proved to be an extremely labor-intensive and time-consuming effort. Tests are now conducted on a clean-as-you-go basis.

6. Air Force Development Test Center

The Air Force Development Test Center (AFDTC), located at Eglin Air Force Base on the northwest coast of Florida, includes land range areas of 724 square miles and water test ranges of 98,000 square miles, covering most of the Gulf of Mexico. AFDTC provides

testing for air-launched tactical and air defense missiles, guided weapons, nonnuclear munitions, aircraft guns and ammunition, as well as aerial targets and electronic combat systems. AFDTC also provides training support for the Air Force's operational commands. Twenty-seven land test areas are dedicated to air-to-surface testing. In addition, water test areas have been used extensively for air-launched weapon testing and training [2].

C. FACTORS DRIVING THE CLEANUP OF UNEXPLODED ORDNANCE

A number of environmental, safety, and mission-related factors are driving the requirement to remediate unexploded ordnance on test ranges. The federal Environmental Protection Agency (EPA) and various state regulatory agencies are beginning to address the problem of unexploded ordnance contamination. In addition, base realignment and closure activities and various mission requirements are forcing the test and evaluation community to give more attention to solving the problems associated with unexploded ordnance contamination.

1. Environmental Regulations

In October 1992, the United States Congress passed the Federal Facilities Compliance Act, Public Law 102-386. Section 107 of this act, titled "Munitions," directed the Administrator of the Environmental Protection Agency to propose and promulgate regulations identifying when military munitions become hazardous waste subject to federal transportation, storage, treatment, and disposal regulations. Drafting the implementing rule has proved to be more complex than initially expected. At present, a rule is expected to be released in July 1995, months beyond the deadline set in the Federal Facilities Compliance Act [6]. The rule, as it is currently being drafted, is expected to have a broader definition of hazardous munitions waste, and could include some currently exempted activities. Current DoD guidance exempts from hazardous waste regulations conventional ordnance firing and explosive activities in training, range clearing, ordnance research and development, and static firing for test purposes. In mid-February 1994, a source at the EPA indicated that the Agency was having difficulty addressing some of the less complex issues and therefore had decided to delay addressing the more complex issues such as unexploded ordnance on active ranges. However, even if the EPA does not regulate unexploded ordnance on test ranges, the individual states may decide to do so.

2. Base Realignment and Closure

Base realignment and closure activities are also forcing the MRTFB to come to grips with the issue of unexploded ordnance. As MRTFB facilities are planned for closure (such as Jefferson Proving Ground), or ranges are programmed to receive activities (such as Yuma Proving Ground), issues of future land use and cleanup must be addressed. Years of testing and training activities on these ranges have left unexploded ordnance, often hidden from view and buried at various depths, scattered across vast areas. As part of its efforts to speed the pace of environmental cleanup efforts at base closure sites, the Department of Defense (DoD) wants future-use considerations to determine cleanup standards. However, in early February 1994, in response to public concerns, the inter-agency task force on base closure, chaired by DoD, established a study group to review the appropriateness of considering future land use when establishing cleanup criteria [7].

The inclusion of future land use considerations in determining cleanup standards is important with respect to unexploded ordnance. If a base being closed is going to be fenced off and left as a wildlife refuge inaccessible to the public, minimal cleanup may be required. However, if the base is going to be turned over to the local community for possible development of a housing complex or a park, extensive cleanup may be required.

As the number of DoD bases decreases, the remaining bases will have to absorb the retained activities and force structure. One hundred and three facilities have been identified for closure as a result of the 1988, 1991, and 1993 Base Realignment and Closure (BRAC) process [8]. News reports indicate the 1995 BRAC will close as many activities as all previous BRACs put together. Ranges receiving activities as the result of BRAC or making facility investments must be concerned with potential unexploded ordnance contamination. As additional land space at the ranges is used, the chance that activities will be sited in areas previously contaminated by testing or training will increase. Before beginning construction, the site must be certified to be clear of unexploded ordnance, for safety reasons. Otherwise, detection and remediation of unexploded ordnance may be required prior to proceeding with a project.

3. Test Mission Requirements

Test mission requirements also drive the need for unexploded ordnance detection and remediation technologies. Many missile/munitions systems test and evaluation programs require the recovery of test articles. Explosive ordnance disposal personnel must enter the impact area to recover these articles. If that area is extensively contaminated with unexploded ordnance from past test programs or training exercises, the risks to explosive

ordnance disposal personnel are multiplied. To minimize the risk involved, these personnel need to be able to accurately detect unexploded ordnance that is hidden from view. In addition, extensive contamination from unexploded ordnance can force the closure of an impact area and preclude future testing there. Sympathetic explosions (explosion of previously unexploded ordnance already on the range) also interfere with test programs by making it nearly impossible to determine if the intended munition exploded on its own. Thus, continued testing becomes impractical in extensively contaminated areas. When this occurs, old impact areas must be closed and new impact areas opened. Once an impact area is closed, future environmental regulations may require it to be cleaned up.

4. Other Factors

From a broader perspective, unexploded ordnance contamination is a safety and economic issue. Several years ago, two children were killed when a 37-millimeter antitank shell exploded at a former defense site in a suburb of San Diego, California [9]. Every year deaths and injuries result from explosive ordnance left behind on former battlefields around the world. Following World War II, approximately fifty professionals in the Netherlands were engaged daily for thirty years clearing unexploded ordnance that continued to cause casualties. Over the same period of time, about 4,000 people were killed and more than 8,000 injured in Libya alone as a result of the explosive remnants of World War II. Exploding munitions can also affect the ecological balance by disturbing soil and vegetation and causing erosion. Unexploded ordnance contamination also prevents the use of potentially valuable natural resources, including agricultural lands, around the world. This can cause further socio-economic harm [10].

D. THE MARKET FOR TECHNOLOGIES

The domestic market for unexploded ordnance detection and remediation technology can be divided by the types of sites, the geographical features of the sites, the extent and types of contamination, and the size of the sites. In this section, we identify, where possible, the number of applicable sites, the varied geographical features that may drive the type of technology needed, and other factors that may constrain the application of certain technologies.

Contaminated sites can be divided into the following types: formerly used defense sites, base closure sites, and active sites. The formerly used defense sites are likely to be the most predictable and dependable market segment. The Army Corps of Engineers has an inventory of at least 500 formerly used defense sites requiring ordnance cleanup [9].

The market segment related to BRAC sites is less predictable because of efforts to reauthorize the Comprehensive Environmental Response, Compensation and Liability Act (Superfund) statute. Nor is there a final decision on the use of future use criteria for determining cleanup standards. The 1988, 1991, and 1993 BRAC rounds are closing approximately 103 sites. An additional 28 sites in 1991 and 134 sites in 1993 have been identified for realignment [11 and 12]. The 1995 BRAC process is expected to be as large as the three previous rounds combined. Not all of the BRAC sites will require ordnance cleanup. However, two test ranges involved would require some form of ordnance remediation, depending on the outcome of the issue of applicable cleanup standards. Jefferson Proving Ground, planned for closure in 1995, would require extensive cleanup if the DoD were to turn it over for alternative uses. Yuma Proving Ground is the receiving site for the mission performed at Jefferson Proving Grounds. Prior to facility construction at Yuma, the area had to be cleared of unexploded ordnance.

The third category, active sites, can be further divided into categories of small construction sites on an installation, former impact areas, or the entire range area.

The types of technology that can effectively meet the need for detection and remediation of unexploded ordnance will vary according to specific site characteristics. The size of the site to be remediated is an important factor. If, for instance, all of Yuma Proving Ground were to be surveyed for contamination and remediation, the size of the test range would prohibit the efficient use of manual or ground-based technologies in the initial stages. However, if a 5-foot-wide strip of land along a roadway needed to be surveyed before beginning utility work, manual or ground-based technologies would be appropriate. Another factor to be considered is the terrain. A different approach might be required for relatively flat terrain with minimal vegetation than for a rocky area containing washes of various slopes and significant vegetation. The soil characteristics, surface features, and clutter would also constrain the application of certain types of detection and remediation systems. Other factors that need to be considered are: the extent and lethality of the ordnance contamination, the size of the objects to be detected and remediated, the time allowed for cleanup, the availability of resources and trained experts, the depth of ordnance, and the applicable cleanup standards. Other significant factors are environmental protection and conservation. Regulatory authorities would probably not permit the natural environment and resident wildlife to be sacrificed in order to clean up unexploded ordnance.

Depending upon the particular site and the cleanup requirements, various technology approaches can be applied to the detection and remediation problem. These

approaches include the application of existing systems, such as hand-held magnetometers and the Surface Towed Ordnance Locator System, or the further development and application of new technologies, such as ground-penetrating radar or infrared systems.

The key issue in determining the market for unexploded ordnance detection and remediation technology is how the factors driving the requirement to remediate will be affected by the costs involved. The House of Representatives Natural Resources Committee is looking into the magnitude of the unexploded ordnance contamination problem, the high costs associated with cleanup, and the state of existing technology. This effort stems from a report issued during the spring of 1992 entitled "Deep Pockets: Taxpayer Liability for Environmental Contamination" [13]. The Congress has also expressed continuing concern over the environmental cleanup and compliance costs the DoD faces. In recent months, the Congress has stated its intention to look closely at the costs associated with the DoD environmental cleanup program and what the taxpayer is receiving for those dollars. Cost will play a major role in determining how far the federal government and the United States taxpayers are willing to go in remediating areas contaminated with unexploded ordnance. Unfortunately, the scope of unexploded ordnance contamination and cost estimates for cleanup have not been determined.

E. SELECTED DoD RESEARCH PROGRAMS

The Department of Defense sponsors and participates in a number of programs that can support research in the area of unexploded ordnance detection and remediation. In this section we specifically discuss Strategic Environmental Research and Development Program, the Central Test and Evaluation Investment Program, the Development of On-Site Innovative Technology initiative, and the Environmental Security Technology Certification Program.

1. The Strategic Environmental Research and Development Program

The Congress established the Strategic Environmental Research and Development Program through Public Law 101-510 on November 5, 1990 (10 U.S. Code 2901-2904). The program is a multi-agency effort that supports environmental quality research, development, demonstration, and application programs. The purposes of the program are to (p. 1055-1062 of 10 U.S. Code):

- address environmental matters of concern to the Department of Defense and the Department of Energy through support for basic and applied research and development of technologies that enhance the capability to meet environment obligations;

- identify research, technologies, and other information developed by the Departments of Defense and Energy for national defense purposes that would help government and private organizations in developing technologies for addressing environmental concerns;
- share Department of Defense and Department of Energy research, technologies, and other information with government and private organizations;
- furnish government and private organizations with data and enhanced data collection and analytical capabilities for conducting environmental research, including global environmental change research; and
- identify private sector technologies that are useful for Department of Defense and Department of Energy defense activities in addressing environmental requirements.

The program is broken into six areas: cleanup, compliance, conservation, pollution prevention, global environmental change, and energy conservation/renewable resources. Developing more efficient and effective means for the remediation of unexploded ordnance is one of the topics of research in the cleanup area. Opportunities exist for academia and private industry to participate through partnerships with participating federal activities and laboratories. Additional information can be obtained by calling the Strategic Environment Research and Development Program Information Line at (703) 525-5300 extension 546 or by writing to: Labat-Anderson Incorporated, 2200 Clarendon Boulevard, Suite 900, Arlington, Virginia 22201 [14].

2. The Central Test and Evaluation Investment Program

The Department of Defense's Central Test and Evaluation Investment Program, managed by the Office of the Deputy Director, Test and Evaluation (Test Facilities and Resources), is another program that may be able to provide support for research and development in this area if its priority is high enough. The goals of the environmental portion of the Central Test and Evaluation Investment Program are to:

- ensure that the test community has the capability to support demonstration, test and evaluation of environmental technology research and development programs;
- leverage Strategic Environmental Research and Development Program projects that could benefit the Major Range and Test Facility Base; and
- develop and demonstrate test technologies that will enable the Major Range and Test Facility Base to meet environmental obligations in a more cost-effective and efficient manner while minimizing any negative impact on the test mission.

Academia and industry can participate in this program through partnerships with one of the Major Range and Test Facility Bases.

3. Development of On-site Innovative Technology

The Federal Advisory Committee to Develop On-Site Innovative Technologies offers a potential opportunity for unexploded ordnance detection and remediation technology demonstration and validation. The committee, which consists of the governors of California, Nevada, Idaho, and Arizona; the Secretaries of Defense, Interior, and Energy; and the Administrator of the Environmental Protection Agency, was formed in 1992 to address barriers to developing and implementing innovative environmental cleanup technologies. The committee has been promoted as the primary effort to develop innovative cleanup technologies using federal-state partnerships at federal facility sites. The committee includes a working group on munitions waste at military sites. The committee has selected Jefferson Proving Ground in Indiana as the site for a controlled test facility to demonstrate technologies for the remediation of unexploded ordnance in the subsurface. Yuma Proving Ground was selected as the demonstration site for technologies for the remediation of unexploded ordnance lying on the surface [15]. The mechanism for participating in this program is unclear at this time.

4. Environmental Security Technology Certification Program

The Department of Defense Office of the Deputy Under Secretary of Defense (Environmental Security) included $15 million in the DoD's fiscal year 1995 budget request to initiate a new program, the Environmental Security Technology Certification Program. The program is designed to demonstrate and validate the most promising innovative environmental technologies that target the Defense Department's most urgent environmental needs and are projected to pay back the investment within five years through cost savings and improved efficiencies. For additional information, contact the Office of the Deputy Under Secretary of Defense (Environmental Security).

F. CONCLUSION

Unexploded ordnance contamination is a significant problem in the United States as well as many other regions around the world. It may be necessary to remediate vast areas of land and water contaminated with unexploded ordnance as military installations are closed or realigned. Current methods of detection and remediation are not adequate to accomplish the task, especially when the ordnance is buried.

A domestic market exists for a variety of technologies to solve the detection and remediation problem. The size of the market will be driven by the availability of cost-effective and efficient methods to address the requirements. Because of the potential cost of remediating vast amounts of land, the underlying requirement to clean up unexploded ordnance at a number of sites is being questioned. The Environmental Protection Agency is drafting rules on when munitions are considered to be hazardous waste, but these rules are unlikely to address the issue of unexploded ordnance on active military installations. For these reasons, we expect the largest segment of the domestic market will be associated with formerly used defense sites and other relatively small sites.

The research and development community needs to cooperate on efforts related to unexploded ordnance detection and remediation technology. A great deal of technology already exists in the sensor area that could be applied to solving the technical challenges.

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Extensive contamination of land with unexploded ordnance has resulted from military conflicts and testing and training activities. Such contamination, coupled with health and human safety risks, planned base closures and realignments, the need to continue to test and train in these areas, and an increasing environmental consciousness, has resulted in a requirement to remediate vast contaminated areas. This paper explores the complexity of remediating advanced munitions in extensively contaminated areas and provides the latest available information on expected regulatory actions. In addition, it provides an overview of opportunities, within Department of Defense programs, for supporting research and development and applying technologies in the area of unexploded ordnance remediation.

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